ITS Field Operational Test Summary

Evaluating Environmental Impacts of ITS Using LIDAR Technology

FHWA Contact: Office of Traffic Management and ITS Applications, (202) 366-0372

Introduction

This ITS Field Operational Test demonstrated and evaluated the use of Light Detection And Ranging (LIDAR) technology in monitoring air quality. LIDAR technology operates in a manner similar to radar, except that the emitted signal is a laser beam rather than a radio wave. A reflected LIDAR signal occurs when a pulsed laser beam scatters off aerosol particles in the atmosphere, analogous to radar signals being reflected and scattered off rain droplets to produce the familiar Doppler radar weather images. Test personnel conducted four separate tests of the LIDAR system in urban and suburban locations in Minnesota under varying weather conditions from July to November 1994.

Project Description

Test personnel installed the LIDAR system and a group of air quality monitoring devices at public events expected to produce significant amounts of traffic and, consequently, pollution. Figure 1 is an illustration of the LIDAR application for air quality measurement. The LIDAR equipment scanned the area above the expected traffic flow. Test personnel placed the air quality monitoring devices in the path of the LIDAR beam near the location of the expected traffic flow.

The LIDAR system sends out pulses of laser light in a known direction. The light scatters off particles in the beam’s path. Suspended aerosol particles in the beam's path reflect some of the light to the instrument. The equipment collects the reflection using a telescope and focuses it onto a sensitive photodetector. The system resolves the spatial distribution of particles by measuring the time it takes for the scattered light to reach the detector. The system can produce two- and three-dimensional maps of the reflected signal by scanning the laser through a sequence of angles.

Test personnel installed the LIDAR system on a platform approximately six meters above the ground and aligned the LIDAR beam to scan the area above the expected traffic flow. [The LIDAR beam is not considered “eye safe” in the first two kilometers of travel and, therefore, had to be elevated for safety reasons.] Elevating the LIDAR system also provided an unobstructed line-of-sight to the air quality monitoring equipment.

Test personnel installed a group of air quality monitoring devices (particulate size distribution, carbon monoxide (CO), and weather) on another platform approximately eight meters in the air. This second platform was directly in the alignment of the LIDAR and close to the expected traffic flow. The group of monitoring devices independently measured air quality indicators for comparison to the readings obtained by the LIDAR equipment. Test personnel set up traffic counters at several locations in the traffic flow.

As traffic from the event exited and dispersed, the LIDAR and the monitoring devices measured the concentration of pollutants in the air. The LIDAR system acquired sequences of single point time histories of the reflected signals coming from the air entering the platform mounted monitoring devices. The LIDAR system interspersed these single point sequences with two- and three-dimensional scans over the access routes of the events. The single point measurements provided the means to establish correlation between the LIDAR signal and the measurements of the conventional monitoring devices. The equipment typically recorded these measurements as three-minute histories. The two-dimensional scans were useful in developing and validating models and typically required two minutes to obtain. The three-dimensional scans were useful in monitoring developments over an entire region and required 10 to 15 minutes to obtain.

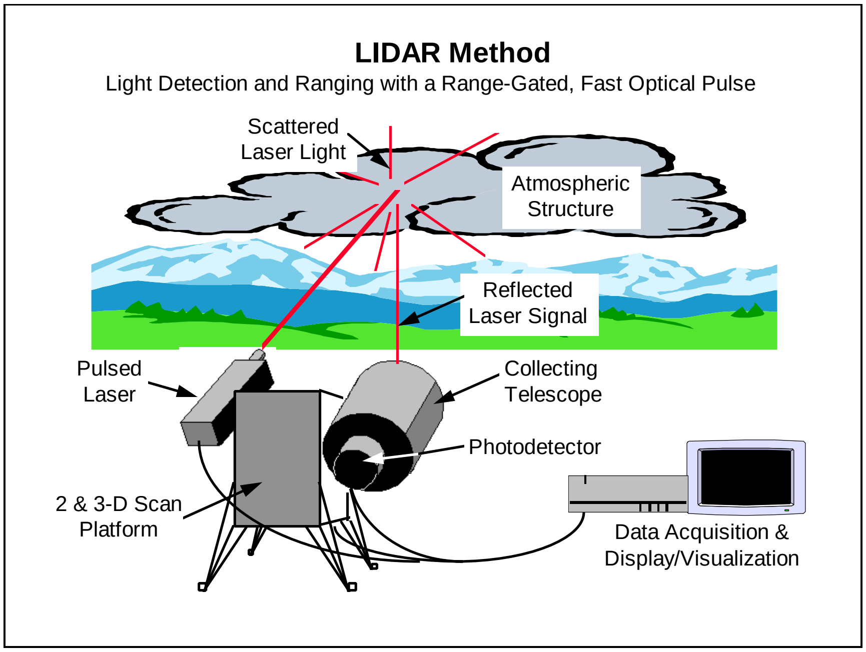

Figure 1: LIDAR System Application for Air Quality Measurement

In addition to the direct air quality measurement tests, the LIDAR test plan also attempted to evaluate the use of a portable traffic management system (PTMS). Test personnel re-routed traffic exiting from public events using portable variable message signs. Test personnel then used the real-time LIDAR pollution data to gauge the effects of the PTMS rerouting. Test personnel used the LIDAR system to monitor whether the PTMS-directed changes in the traffic conditions in a local area brought about significant reductions in pollutant concentrations or merely shifted the problem to a different location.

Results

Test personnel were able to answer many questions regarding the usefulness of the LIDAR technology in pollution measurement, but were not able to collect sufficient data to analyze the impact of the PTMS.

Test personnel concluded that the LIDAR system could be used as a quantitative indication of particle concentrations with certain important restrictions. To be useful in this context, the size of the particles to be measured must be on the same order as the wavelength of the laser employed. Test personnel must also make auxiliary measurements of the size distribution to rule out the possibility of abnormal size distributions or changes in particle composition. The system, however, probably cannot be used as a quantitative measurement tool because of the uncertainties associated with particle size and composition. In other words, the LIDAR system can tell what kind of particulates are suspended but cannot reliably measure the amount of pollution.

Test personnel also concluded that the LIDAR system could only be viewed as an indirect, qualitative indicator of CO levels, and then only under certain circumstances. The system could be used to identify roadway-generated CO plumes that were likely to exceed allowable levels. Qualitative measurements of CO, however, would require the use of more sophisticated LIDAR systems tuned to measure CO concentrations more directly.

Additionally:

- The system can measure concentrations of particles whose sizes are on the same order of magnitude as the wavelength of the laser employed. Concentrations of particles much smaller or larger than the wavelength of the laser, however, may make up a significant portion of the suspended matter in the air. Testers concluded that any deployment of LIDAR technology must also include auxiliary measurements of the particle size distribution to rule out the possibilities of abnormal size distributions or changes in particle composition.
- Test personnel observed that the system requires several trained operators to set up and oversee the operation. They also lamented the lack of real-time data display. Test personnel had to convert all data to a common format and to enter it into a single program in order to produce correlated maps and images. Complete results of the test, therefore, were not available for several months. Once all of the information (from LIDAR, the monitoring devices, and a GIS database) were converted and combined, personnel were able to produce quantitative maps and other exhibits of aerosol concentrations. These maps were understandable with a minimum of study.

The system is easily portable and reasonably reliable, but encountered several problems in the field:

- The test laser beam was not considered “eye-safe” in the first two kilometers of travel. Test personnel, therefore, had to ensure that they did not aim the LIDAR at the street level. They also had to assure that a laser safety officer was present during the tests.
- Cold weather (at or below freezing - 0^0C) posed some difficulties for the equipment. The LIDAR device became inoperable at these temperatures until test personnel moved the equipment to a more protected location and warmed it. The particle sensors on the monitoring platform also had to be sheltered and warmed.

The test was unable to gather sufficient data to evaluate the PTMS. Some of the originally scheduled events either did not take place or were much smaller than expected. Therefore, test personnel chose alternative events and took measurements at these events. Unfortunately, the variations in site conditions and weather made it impossible to collect enough data under similar conditions to assess the pollution mitigating effects of the PTMS.

Test personnel recommended several possible uses and improvements for the LIDAR system and the testing procedures:

- The system has excellent potential for helping to develop and validate pollution source and dispersion models. The data should be available for display in near real-time. Such a display should include a time stamp and the direction heading of the LIDAR beam.

- Future tests should include one or more "calibration" measurements using particle-sizing instruments.
- Any future test should also address the data conversion bottleneck of making all the data available for analysis on a single machine.
- Local air quality personnel or EPA air quality employees should assist with the siting and operation of the pollution sampling equipment.

Legacy

The equipment evaluated in this test was a prototype system. There are no plans to continue the development of this system.

Test Partners

Federal Highway Administration

IBM

Los Alamos National Laboratory

Minnesota Department of Transportation

Santa Fe Technologies

University of Minnesota

References

Chakravarty, S., et al, Wide-Area Remote Sensing of Air Quality Impacts of ITS, March 1995.

Hofeldt, D., Preliminary Summary of Findings of LIDAR Project Evaluation (Draft), University of Minnesota, December 1995.